Please write your name in the space provided at the top of each page. There a total of 100 points on the exam and 9 pages total (including cover page). Be sure you have all pages. This is a closed book exam but you are welcome to use a calculator. PLEASE confine your answers to the space provided and, for the written questions, please write as legibly as possible.
The following multiple choice question (1-20) are each worth 3 points. Please clearly circle the best answer for each question.

1. If the osmotic pressure of a tubular structure is 50 mm Hg, and that of the surrounding solution is 70 mm Hg, in which direction will there be net fluid flow? (assume there are no other pressures affecting fluid flow)
   A. Into the tubular structure
   B. Out of the tubular structure
   C. There will be no net fluid flow in either direction
   D. There would be destruction of the tubular structure because Hg is toxic

2. The GHK (Goldman-Hodgkin-Katz) equation is the equation of choice to calculate
   A. the osmotic pressure exerted by impermeant solutes
   B. the equilibrium potential for Mg$^{2+}$
   C. the reversal potentials for some kinds of ion channels
   D. the threshold voltage for generation of an action potential

3. In skeletal muscle contraction, a fall in intracellular ATP concentration would result in
   A. decreased uptake of Ca$^{2+}$ into the sarcoplasmic reticulum
   B. muscle relaxation
   C. inability to form crossbridges
   D. greater dissociation of myosin heads from actin binding sites

4. The opening of Ca$^{2+}$-activated K$^+$ channels in some neurons reduces the frequency of action potentials by
   A. extending the absolute refractory period
   B. reducing the driving force on Na$^+$ ions entering the cell
   C. causing accommodation
   D. extending the relative refractory period
5. Smooth, graded contraction of skeletal muscle is promoted by

A. stretching of the series elastic component
B. slow formation of crossbridges
C. tetanus, which results from an accumulation of Ca$^{2+}$ with repetitive stimulation

[D] A and C
E. none of the above

6. Which transport method below relies on the energy stored in the Na$^+$ concentration gradient across the cell membrane?

A. delayed rectifier K$^+$ channels
B. gap junction channels
C. Ca$^{2+}$ pumps
[D] some exchange carriers

7. Diffusion through the lipid bilayer –

[A] sometimes depends on the pH of the diffusing substance
B. is faster for hydrophilic substances
C. requires ATP
[D] is independent of the concentration gradient of the diffusing substance

8. $I_h$ (hyperpolarization-activated; also called $I_l$) channels

A. are gated by voltage and stretch
B. turn on at the peak of the SA node action potential
[C]. produce the slow depolarization phase of pacemaker action potentials
D. are K$^+$-selective channels

9. Glucose is transported across the intestinal epithelium from lumen to blood by

A. glucose pumps
B. glucose/Na$^+$ co-transporters
C. glucose ion channels
D. simple glucose carriers
[E] B and D
F. all of the above
10. A prolonged elevation in extracellular $K^+$ concentration would

- [X] make $E_K$ more negative
- [ ] cause accommodation in neurons by inactivating $Na^+$ channels
- [ ] cause delayed rectifier $K^+$ channels to stay open longer
- [ ] reduce the threshold for action potential generation in the initial segment

11. The increase of cardiac contractility caused by norepinephrine is due to

- [X] Increased calcium re-uptake by the sarcoplasmic reticulum
- [ ] Prolonged action potential duration
- [X] Increased intracellular free $Ca^{2+}$
- [ ] More favorable overlap of actin and myosin filaments

12. During the compression phase of the Valsalva maneuver, the decrease in cardiac output is due to

- [X] Reduced venous return
- [ ] Reduced heart rate
- [ ] Breath-holding
- [ ] Peripheral vasoconstriction

13. In a parallel circuit as illustrated below, flows through both pathways (A and B) are initially the same. Then the resistance in pathway A is doubled but with no effect on either arterial or venous pressure ($P_a$ and $P_v$) or on the resistance of pathway B. Flow in pathway B will

- [X] Double
- [ ] Remain the same
- [ ] Be reduced by half
- [ ] Be indeterminate due to inadequate information

\[
\frac{\Delta P}{R_A} \Rightarrow Q_1 = \frac{\Delta P}{R_B}
\]

\[
\frac{\Delta P}{R_A} = \frac{\Delta P}{R_B}
\]

\[
2x + x = 2x
\]
14. The phenomenon of autoregulation in a perfused organ in response to increased perfusion pressure is attributed to

A. Constriction of resistance vessels by sympathetic stimulation
B. Dilation of resistance vessels by sympathetic inhibition
C. Constriction of resistance vessels by intrinsic factors within the organ
D. Dilation of resistance vessels by intrinsic factors within the organ

15. During steady-state moderate exercise at 4 times the resting oxygen consumption, a subject's arterial-mixed venous oxygen concentration difference doubles. Cardiac output

\[ \text{C.O} = \frac{2 \sqrt{V_{O_2}}}{2 \left( R_{V} - P_a \right)} \]

A. Doubles
B. Increases by four times
C. Stays the same
D. Impossible to say with information given

16. Arteriolar vasodilation at constant arterial pressure will

A. Increase both flow and pressure in the downstream capillaries
B. Increase flow but decrease pressure in the downstream capillaries
C. Decrease both flow and pressure in the downstream capillaries
D. Decrease flow but increase pressure in the downstream capillaries

17. Which of the following is not a characteristic of the coronary circulation?

A. Flow is restricted during systole
B. Flow is largely controlled by autonomic nerves
C. Oxygen extraction is always high
D. Flow is proportional to cardiac oxygen consumption

18. The second heart sound is most closely associated with

A. The P wave of the ECG
B. The QRS complex of the ECG
C. The T wave of the ECG after T wave
D. No particular wave of the ECG
19. Electrical conduction is slowed in the A-V node because

A. No nerves are present there
B. Nodal cells have slow action potential depolarizations
C. Transmission is via gap junctions
D. Of vagal stimulation

20. Increased arterial pulse pressure is least likely to be associated with which of the following?

A. Decreased arterial compliance
B. Increased preload
C. Increased cardiac contractility
D. Increased heart rate

21. Cation $X^{2+}$ is membrane permeant and has a Nernst potential of +30 mV.

A. (3 points) Is the concentration of this ion greater inside or outside the cell? Explain with a diagram of the cell.

B. (1 point each, 4 points total) For each of the cell membrane potentials listed below, indicate whether there would be NET INFLUX (I), NET EFFLUX (E), or NO NET FLUX (N) of cation $X^{2+}$:

\[\begin{align*}
\text{N} & +30 \text{ mV} \\
\text{I} & -30 \text{ mV} \\
\text{E} & 0 \text{ mV} \\
\end{align*}\]
22. (4 points) A cell is permeable to divalent anion $X^{2-}$, whose intracellular concentration is 10 mM and extracellular concentration is 1 mM. At what membrane potential will there be no net flux of anion $X^{2-}$? Assume the temperature is 37°C. Show your work and don’t forget UNITS in your answer.

\[
X^{2-} \quad \begin{array}{c} \text{10 mm} \\ \text{1 mm} \end{array}
\]

\[
N_e = \frac{-RT}{F} \ln \left( \frac{C_i}{C_0} \right)
\]

\[
= -\frac{6.1}{2} \log \left( \frac{10}{1} \right)
\]

\[
= \frac{-2}{2} \log \left( \frac{10}{1} \right)
\]

\[
= -2 \log (10) = -20.5 \text{ mV}
\]

**+4**

23. (1 point each, 5 points total) Indicate whether each statement is TRUE (T) or FALSE (F):

**F** A. During skeletal and cardiac muscle contraction, there is a shortening of the actin (thin) and myosin (thick) filaments; these filaments are re-polymerized back to their original lengths during the relaxation phase.

**T** B. During skeletal muscle contraction, the action potential spreads down the T-tubule, where it causes Ca$^{2+}$ to be released from the adjacent sarcoplasmic reticulum.

**T** C. Gap junction channels are present in cardiac muscle and intestinal smooth muscle, but not in skeletal muscle.

**F** D. Ca$^{2+}$ regulates contraction in all three kinds of muscle by binding to troponin, thereby causing tropomyosin to move out of the way of the myosin binding site on the actin filament.

**T** E. One difference between an EPSP and a skeletal muscle end plate potential (EPP) is that the EPSP is generally subthreshold, whereas the EPP is always suprathreshold under normal conditions.
24. (1 point each, 4 points total) For each selection in the sentence below, underline the correct word or phrase.

Isovolumic contraction (IVC) of the left ventricle begins shortly after the (P wave) (QRS complex) (T wave). During IVC, the mitral valve is (open) (closed), the aortic valve is (open) (closed), and the atria are (filling) (emptying) (isovolumic).

25. (8 points) A patient has high blood pressure. You have a number of drugs at your disposal to possibly give this patient. Briefly explain, based on the physiology of the cardiovascular system, how the actions of these drugs would tend to lower the patient's blood pressure.

A. β-adrenergic blocker (β-blocker): β-adrenergic receptors receive sympathetic innervation in heart that makes HR↑; so blockers would make HR↓ since CO = HR × SV; ΔHR = ΔCO - SO lower BP. Also decreases contractility.

B. α-adrenergic blocker: Decrease sympathetic stimulation from sympathetic nerves that cause HR↑. If one blocker fails then HR↑ in tissue, α-adrenergic receptors receive sympathetic innervation and constrict by this force, α- and blockers would reduce amount of constriction.

C. Ca²⁺ channel blocker: Calcium channel blockers would reduce contractility of heart and contractility ↑ → SV↓ → CO↓ → BP↓ urine fluid loss

D. Diuretic (increases urine fluid loss): decreases blood volume - SO venous return ↓; EDV ↓; SV↓ → ↓ BP↓

26. (4 points) In the space below, draw a normal left ventricular pressure-volume loop and label the axes. Using the loop, illustrate how the heart, faced with a decreased preload, could restore normal stroke volume by increasing contractility.

 systolic pressure curve would be higher when contractility increases
diastolic curve would move down b/c ejection fraction ↑ so 1 → 2 will get longer again.
- By using higher ejection fraction from contractility, Heart can restore normal stroke volume.
27. (8 points) In the two graphs below, cardiac output is plotted vs. right atrial pressure. In each graph the solid curves represent normal cardiac and vascular function curves. One of the curves then changes and the operating point moves from 1 to 2. Then the other curve changes in response and the operating point moves from 2 to 3. For each change, describe briefly the mechanism whereby this could have occurred.

**Graph A, point 1 to point 2:**
- drop in total peripheral resistance makes vasc function curve up. (vasodilation)

**Graph A, point 2 to point 3:**
- increased contractility of heart makes cardiac function curve up

**Graph B, point 1 to point 2:**
- heart failure or decrease in contractility of heart makes cardiac function curve rotate down.

**Graph B, point 2 to point 3:**
- Increase in blood volume (venoconstriction) moves vascular function curve up
- or through action of ADH
  - fluid